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COMPUTER REQUIREMENTS:

DATA CONSTRUCTION, INPUT, and INITIAL PROCESSING.

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INTRODUCTION and SUMMARY

The processing of camera data by the computer, especially in the input and identification stages, will be dependent upon the exact form of that data. The measurements enter the computer in words which contain a "compressed" amount of information. The method by which each word is constructed by the camera electronics dictates how it will be dismantled after it arrives in the computer.

Thus it seems proper, before encountering the details of the identification sequence, to discuss what the camera electronics does and how the computer should handle the transit time and magnitude data from the scanned targets.

In this memorandum, we will not attempt either to design the electronics nor even to choose an optimum system. Our concern will be to present a particular configuration which appears to satisfy the requirements, and to discuss it in sufficient detail to permit a concrete assessment of what the computer must do during input of the data and identification of targets.

It remains for a later phase of the contract to discuss detailed design parameters. Results of investigations during the past two years in this area are presented both in published literature[1, 2, 3] and in memoranda internal to Control Data Corporation.[4, 5, 6, 7, 8]

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1 Lillestrand, R. L. and Carroll, J. E., "Self-Contained System for Interplanetary Navigation, Am. Astronaut. Soc Preprint 61-95 (August 1961).

In summary, this memorandum discusses the detection process wherein information passes successively through the camera slits, photomultiplier, transmitter, receiver, electronics, buffer and finally comes to rest in the computer memory. Two signals are actually processed: phototube anode current and multiplier voltage. The first is used to measure entrance and exit times of the target image in the slits. The multiplier voltage changes with target intensity to protect the tube and is therefore useful as an intensity indicator.

Since the instrument capsule is detached from the vehicle, the photomultiplier outputs are transmitted immediately to the latter for processing. These signals are digitized and fed to the computer

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2 Control Data Corporation Research Division, Final Report: Investigation of Navigation in Cislunar Space, ASD-TDR-62-960, Contract No. AF 33(657)-8215, Minneapolis, Minnesota, December 17, 1962.

3 Harrington, D. C., "Noise Error Analysis of an Optical Star and Planet Scanner", (paper presented at the National Aerospace Electronics Conference, Dayton, Ohio, May 13-15, 1963)

4 Control Data Corporation Research Division, "Error in Average Transit Time", by Charles B. Grosch, TM-109, Minneapolis, Minnesota, June 1962.

5 Control Data Corporation Research Division, "Application of a SCANAV Camera for Attitude Determination of a Spinning Sounding Rocket," coordinated by Joseph E. Carroll, TM-112, Minneapolis, Minnesota, October 1962.

6 Control Data Corporation Research Division, "Application of a Concentric Mirror System to the SCANAV Camera", by E. A. Mazorol, Jr., TM-113, Minneapolis, Minnesota, November 27, 1962.

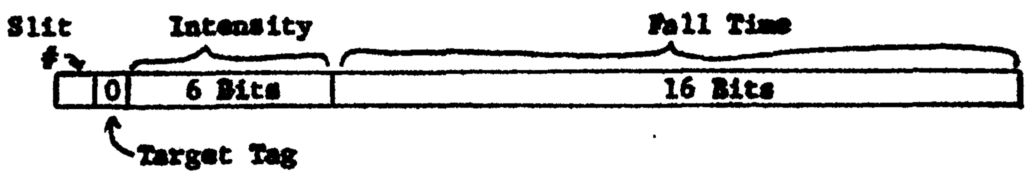
7 Control Data Corporation Research Division, "Fast Scan Pulse System with Optically Limited Accuracy", by D. C. Harrington, TM-120, Minneapolis, Minnesota, January 4, 1963.

8 Control Data Corporation Research Division, "Accuracy of Four Scanning Camera Systems Covering a Wide Scanning Time Range", by D. C. Harrington, TM-122, Minneapolis, Minnesota, January 24, 1963.

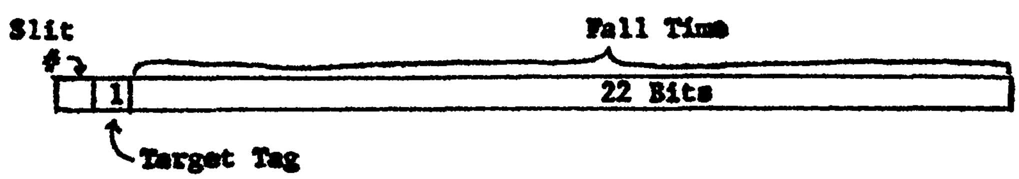
via a high-speed buffer capable of storing a small number of sequential words until the computer is ready to receive them. 48 bits of information are generated in two 24-bit words for each target transit of a given slit. The first word contains the time that the photomultiplier anode current becomes greater than the bias level. This "rise time" is in units of 10 μseconds and hence can tell time up to $(2^{24}-1) \times 10^{-5} = 167.8$ seconds, long enough to encompass ten scans of 10 seconds each.

The structure of the second 24-bit word depends upon the target:

STAR



PLANET



The first two bits in each case contain similar information: bit #1 - slit number (0 = #1, 1 = #2), bit #2 - target tage (0 = star, 1 = planet). The last twenty-two bits contain, for extended targets such as planets, the time that the photomultiplier anode current falls below the bias level. The least bit here also measures 10 μseconds so that $(2^{22}-1) \times 10^{-5} = 41.9$ seconds can be contained. The "fall time" is required in case measurements are desired on the trailing edge of a planet.

To keep instrumentation to a minimum, the same fall time gating is used for stars. However, a 6-bit intensity code overwrites the upper portion of this fall time.

Now 24 bits is longer than needed for either target. The largest planet would still only require an 18 bit fall time; and a star would only require six bits. Thus 20 and 14 bits are the minimum necessary. For word length consistency and to keep operations for different targets as similar as possible, 24 bits was chosen, however.

In the computer, the words are stored by a short interrupt program in two series of lists. The first is a pair of lists, one for each slit. Those targets which are definitely extended bodies are retained here. Both the rise and fall times (24 bits a piece) are kept; they are stored alternately. Thus, say, the even locations contain rise times, add locations contain fall times.

The second series of lists, for stars (or other targets whose intensities do not exceed an upper bias level), is really three lists. Lists #1 and #3 contain the transit times for slits #1 and #2 respectively. By transit time is meant the average of the rise and fall times. List #2 contains the intensity codes for both slits. Since each is only six bits long, even a 12-bit machine could retain two codes in one word. The convention could be, say, that the most significant bits belong to slit #1, the least significant to slit #2. The order in which entries are made are compatible with those in lists 1 and 3 for purposes of identification.

Let us assume that we make allowances for five extended body targets and fifteen stars for each camera scan. Then lists 1, 2, and 3 need each to be fifteen locations long per scan. If data is gathered for ten scans, this amounts to 450 locations. Similarly, for the planets, 200 locations are needed (2 slits, 2 times, 10 scans). This information is all, of course, temporary and will be destroyed during the process of identification.

These requirements are the only ones discussed in the present memorandum. A future publication (TM-9552-8) concentrates on the computer interrupt program (which accepts, processes, and disseminates the camera data to the respective lists) and determines memory requirements and execution speeds for this program.

I. TARGET DETECTION

The basic components of the detector system are shown in Figure 1 and the important system characteristics listed in Table I. As the target traverses the crossed-slit configuration on the camera focal surface, pulses are generated by the photomultipliers which can subsequently be used for determination of transit time and intensity.

It is to be noted from Table I that the slit width is the same as the blur circle diameter (i.e., the diameter which contains 85% of the image energy) and both are equal to 20 seconds of arc. Of course, as seen in Figure 1, the slits are inclined to the vertical by 30° so that the effective slit width is 20"/cos 30° = 23".1. Since the target location accuracy is ten seconds of arc, interpolation of the slit is evidently necessary. As has been shown,[3] an interpolation of at least 1/6 of the slit width ensures that false targets and missed targets will be negligible. The same reference shows that a given angular accuracy σ (in seconds of arc), scan period T (in seconds of time), target photographic magnitude m_p, and camera aperture D (in centimeters) must all be related by*

$$D\left[\sigma^3 T\right]^{1/2} \geq 61 \times 10^{+.2 m_p} . \tag{1}$$

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* We have altered the values in Reference 3 to correspond to an effective slit width of 23".1.

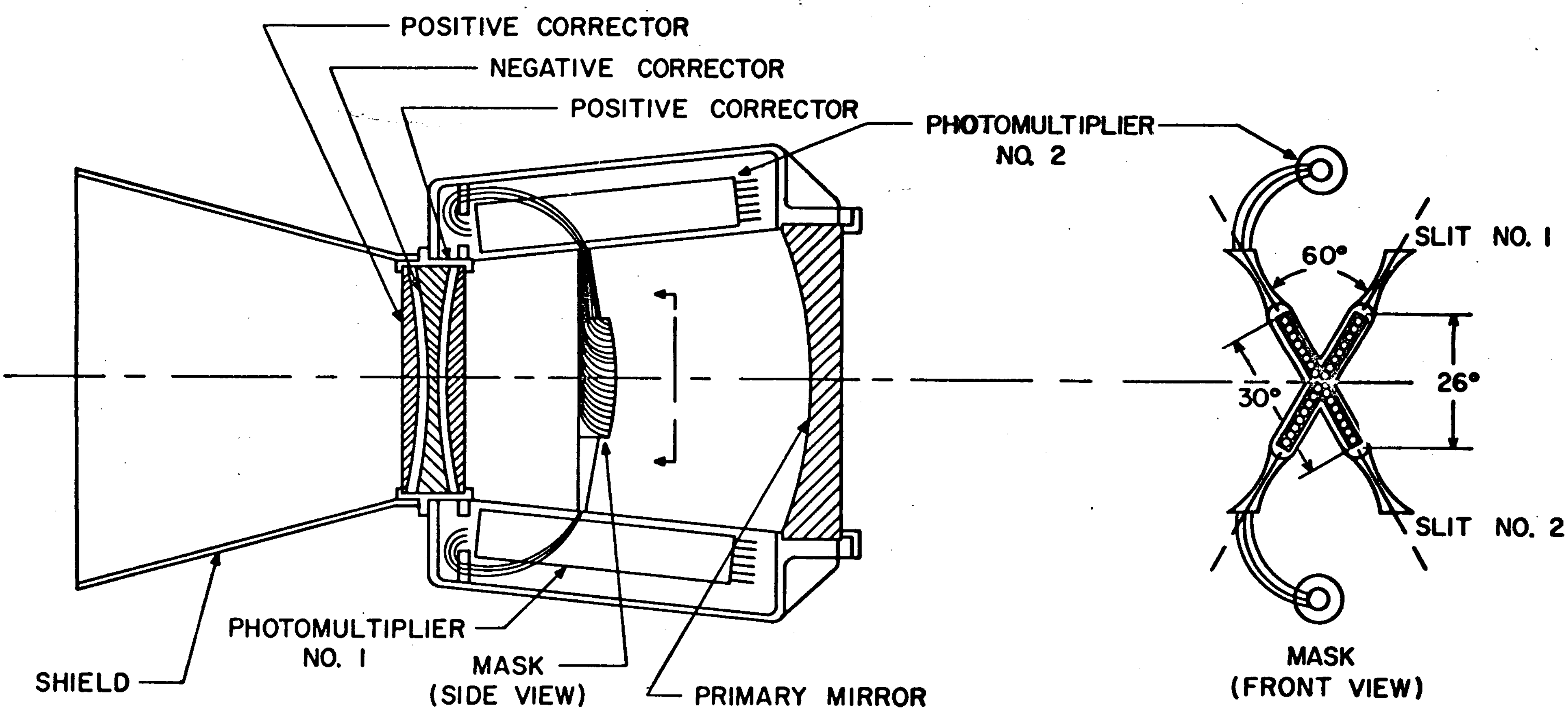


FIGURE 1: REPRESENTATIVE WIDE-ANGLE CAMERA

TABLE I: Characteristics of Scanning Camera

Type of Camera	Baker-Nunn
Aperture	4 inches
Field of View	30 degrees
f Number	1.0
Effective Focal Length	4.0 inches
Diameter of Primary	5.5 inches
Diameter of Focal Surface	2.0 inches
Diameter of Blur Circle	20 seconds of arc
Focal Surface	Slits can be made to conform to whatever surface minimizes optical aberrations
Slit Width	20 seconds of arc
Spectral Region	3000 Å to 6500 Å

(Note that an interpolation factor < 1/6 means an RMS angular error $\sigma < 3''.85$.) This relation makes the assumption that signal photon noise is the factor limiting accuracy which is true for proper selection of the photomultiplier. Figure 2 shows the relation (1) for several spin periods. We see that stars brighter than -2.5 magnitude and spin periods longer than ten seconds give errors no greater than 3.5 seconds of arc.

Figure 3 shows to what time accuracy the photomultiplier pulses must be measured for a given angular resolution and scan period combination in Figure 2. For example, a period of ten seconds for the camera scan requires that a clock accurate to 8 μseconds must be available in order to keep clock errors below the expected angular errors for targets less bright than -1.5 magnitude. A 10 μsecond clock for the same scan period would keep errors at 1 second of arc for stars brighter than -1 magnitude.

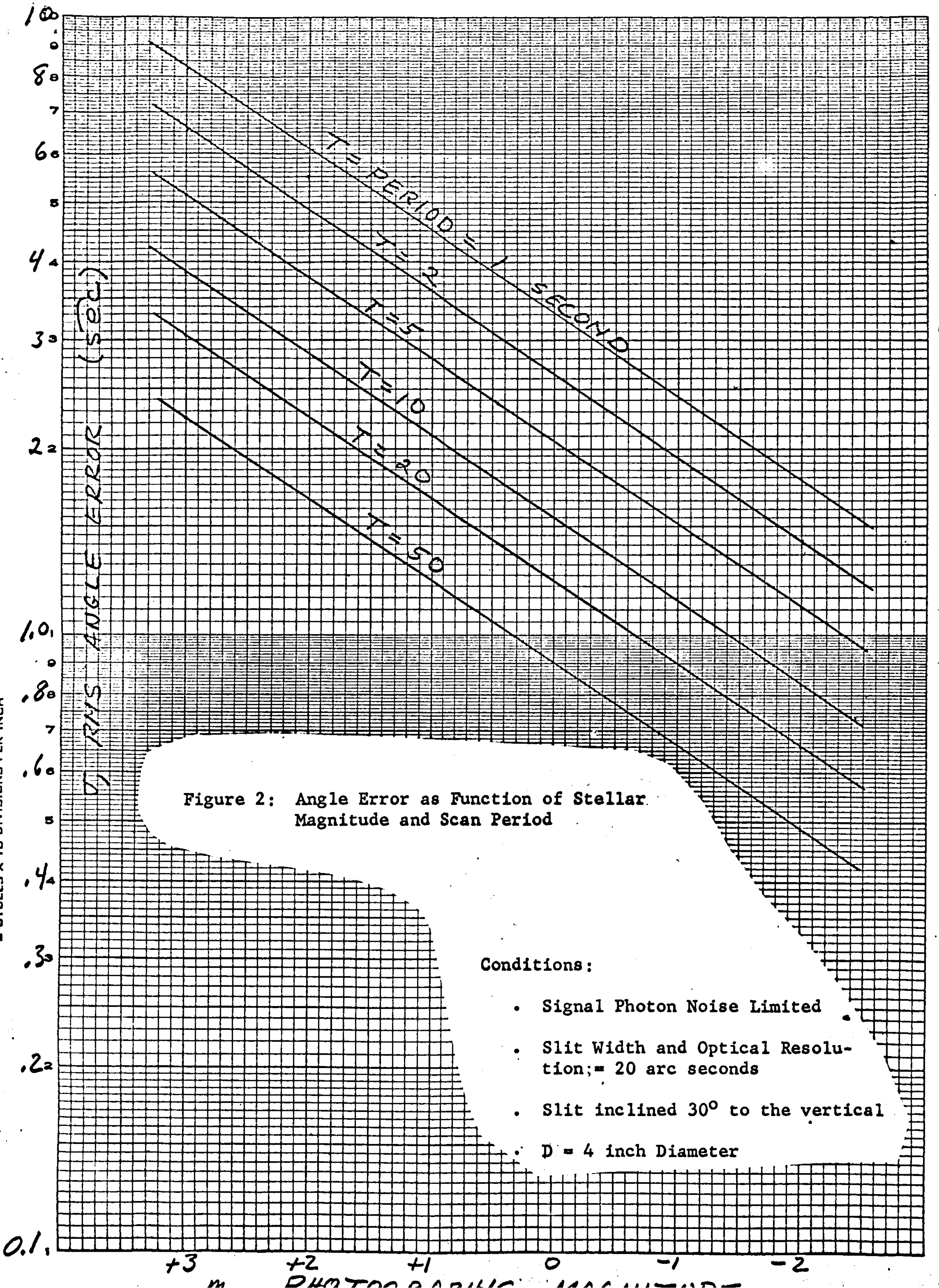
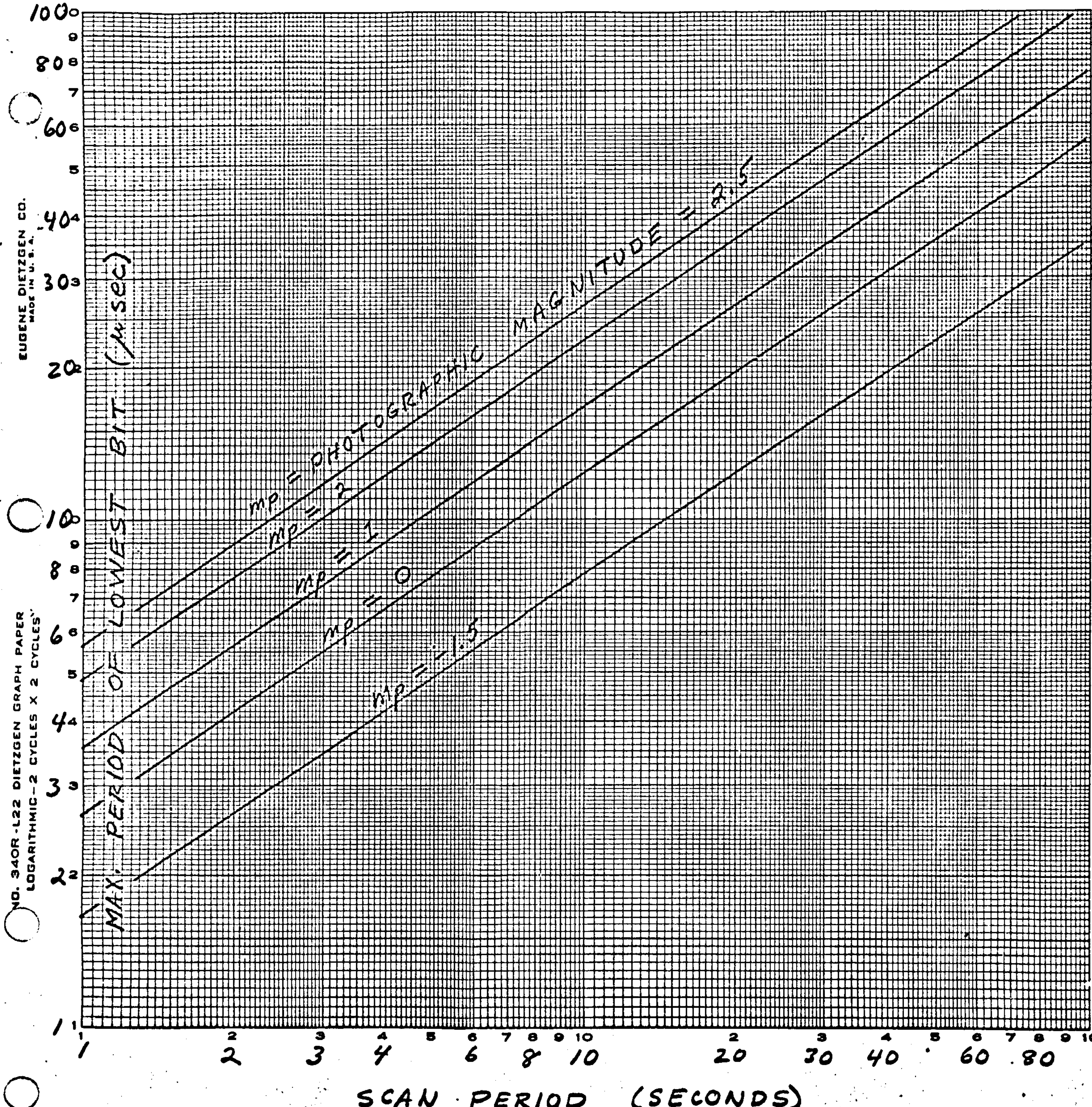


Figure 2: Angle Error as Function of Stellar Magnitude and Scan Period

Conditions:

- Signal Photon Noise Limited
- Slit Width and Optical Resolution; = 20 arc seconds
- Slit inclined 30^{o} to the vertical
- D = 4 inch Diameter

Figure 3: Clock Resolution Required to Keep Clock Error Below Angular Measurement Error of Figure 2



II. FORMATION OF DATA

A. Photomultiplier Outputs

Because of the requirement that the phototube detect both stars and planets, some very bright objects may be observed. To prevent damage to the phototube due to high current it is planned that the gain will be changed to maintain the anode current constant. Thus the multiplier voltage will be a measure of the magnitude of the target while the fast rise and fall times of the phototube anode current will be used for transit time measurements. Figure 4 shows both the multiplier voltage and anode current as a function of target magnitude. This figure is meant to be representative the EMI 6094S tube would not be the exact one used due to vibration difficulties.

The zero signal voltage on the tube, E_o, is about 1900 volts so that an 1150 volt pulse will be generated for a 1st magnitude star. Thus the two pulse shapes will appear as in Figure 5 (for a 1st magnitude target). Note that the E_m curve has a slower rise time than the anode current curve. The latter is therefore more useful for time measurements while the former can be measured for magnitude while at the same time protecting the tube from excessive current damage.

B. Camera Electronics

The electronic instrumentation between the photomultipliers and the computer is necessarily divided into two parts. Because the

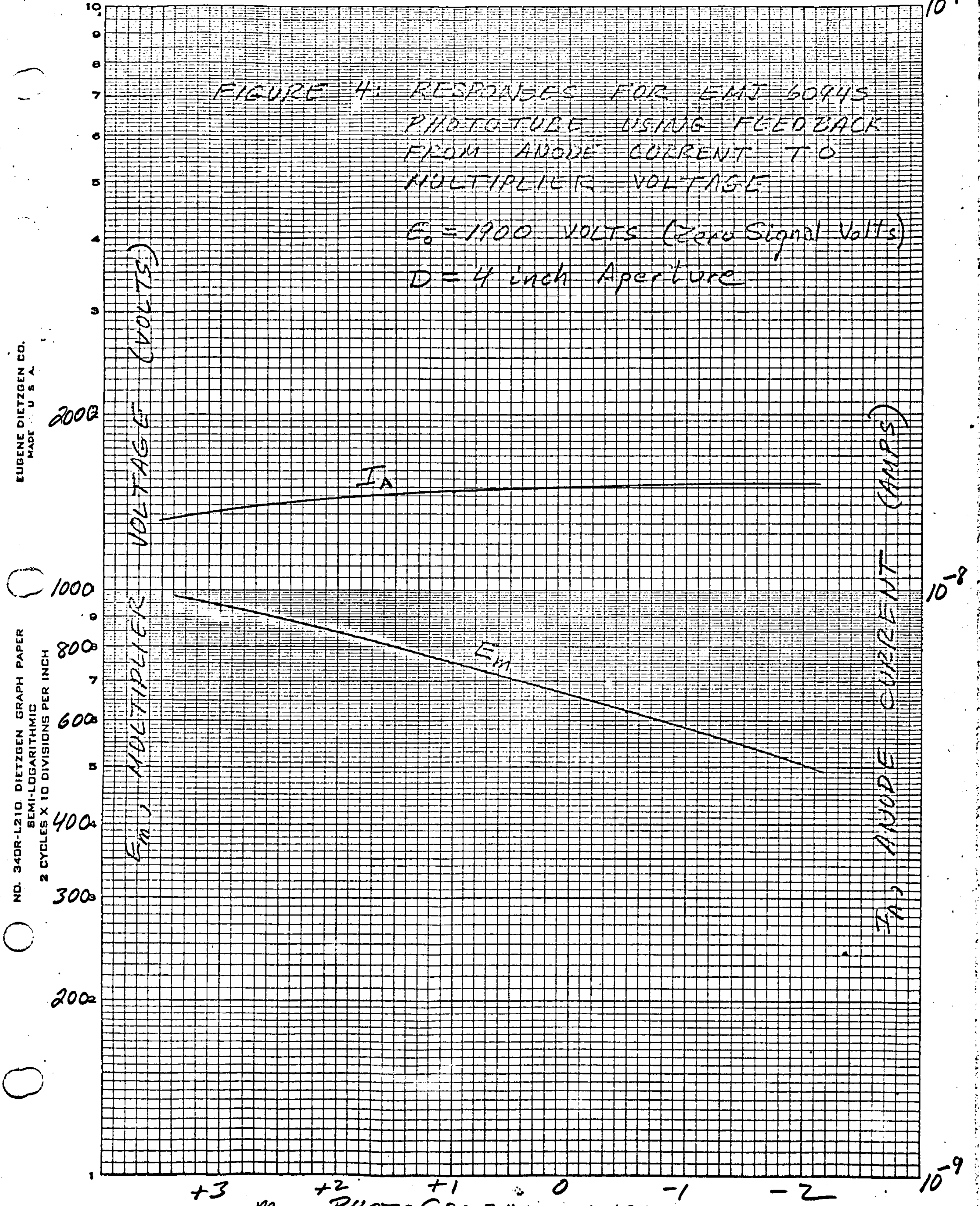


FIGURE 4: RESPONSES FOR EMI 6094S PHOTOTUBE USING FEEDBACK FROM ANODE CURRENT TO MULTIPLIER VOLTAGE

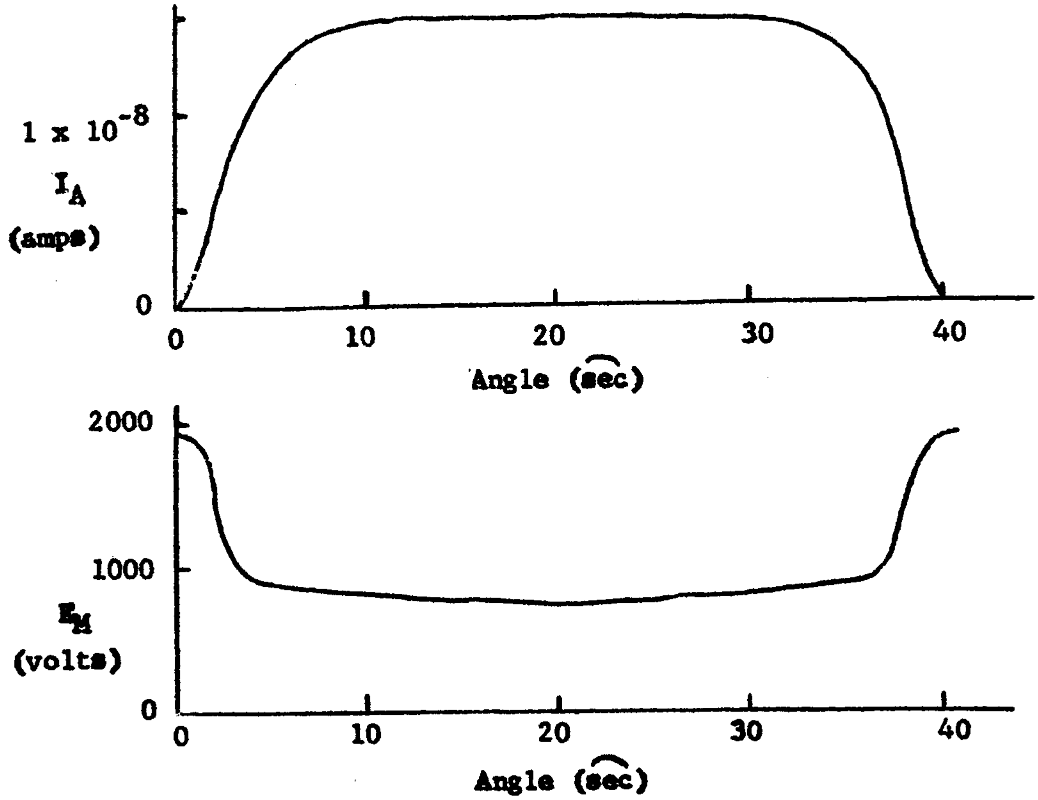


Figure 5

detector will be separate from the space vehicle and not coupled to it by anything which might disturb its (the detector's) motion, information will be transmitted from the detector to the vehicle, a distance between six inches and four feet.

1. Capsule Instrumentation

To minimize the instrumentation in the detector capsule, both the anode current and multiplier voltage pulses are to be sent immediately to the mother vehicle for analysis. This does not require four separate transmission channels but can be done by modulating a carrier frequency as shown schematically in Figure 6. For example, the current pulse, I_{A1}, from photomultiplier #1 changes

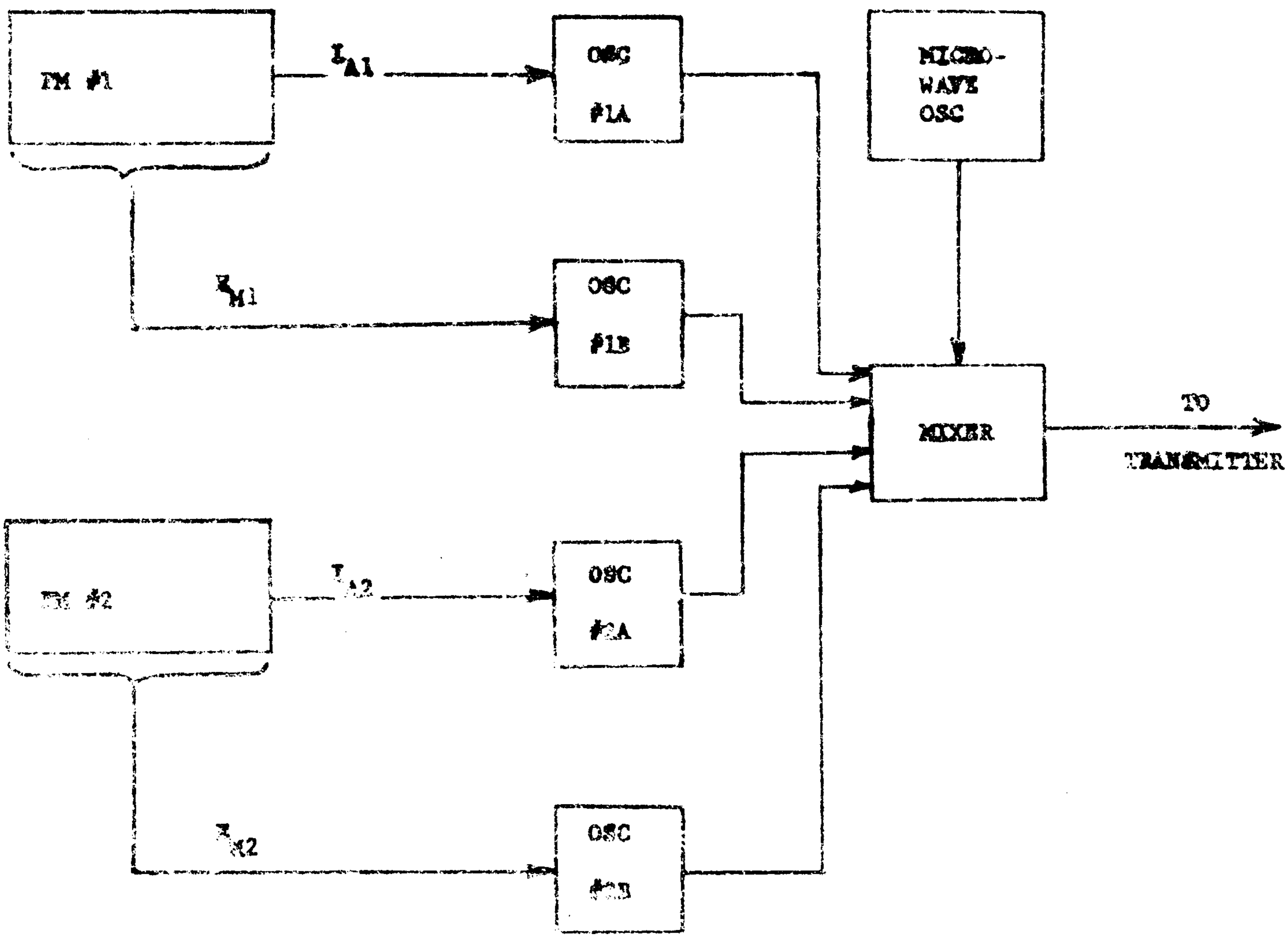


Figure 6: Schematic Representation of Capsule Electronics

the frequency of the output of oscillator #1A which in turn amplitude modulates a master micro-wave oscillator. The master carrier is then transmitted to the mother vehicle for processing. All four outputs of the two photomultipliers similarly shift their respective oscillator frequencies. The signal transmitted has, then, a bandwidth twice the value of the highest modulator frequency and is centered on the master oscillator frequency.

2. Vehicle Instrumentation

The electronics required in the space vehicle itself is schematically shown in Figure 7. There, the signal transmitted from the capsule is received and split as to frequency into its four information components. These are each demodulated resulting in the original anode currents and multiplier voltages.

Each anode current is then used to measure the times that the pulse rises above and falls below a given bias level. The average value of these two times is what constitutes the target transit time.

The multiplier voltage measures the target intensity using some device such as a pulse-height analyzer. Six bits, or 63 levels could be resolved which would be about equal to the expected correlation of measurement to reality.

C. Data Logic

It is planned to construct two 24-bit words for each target transit of a given slit. The method of construction is shown in

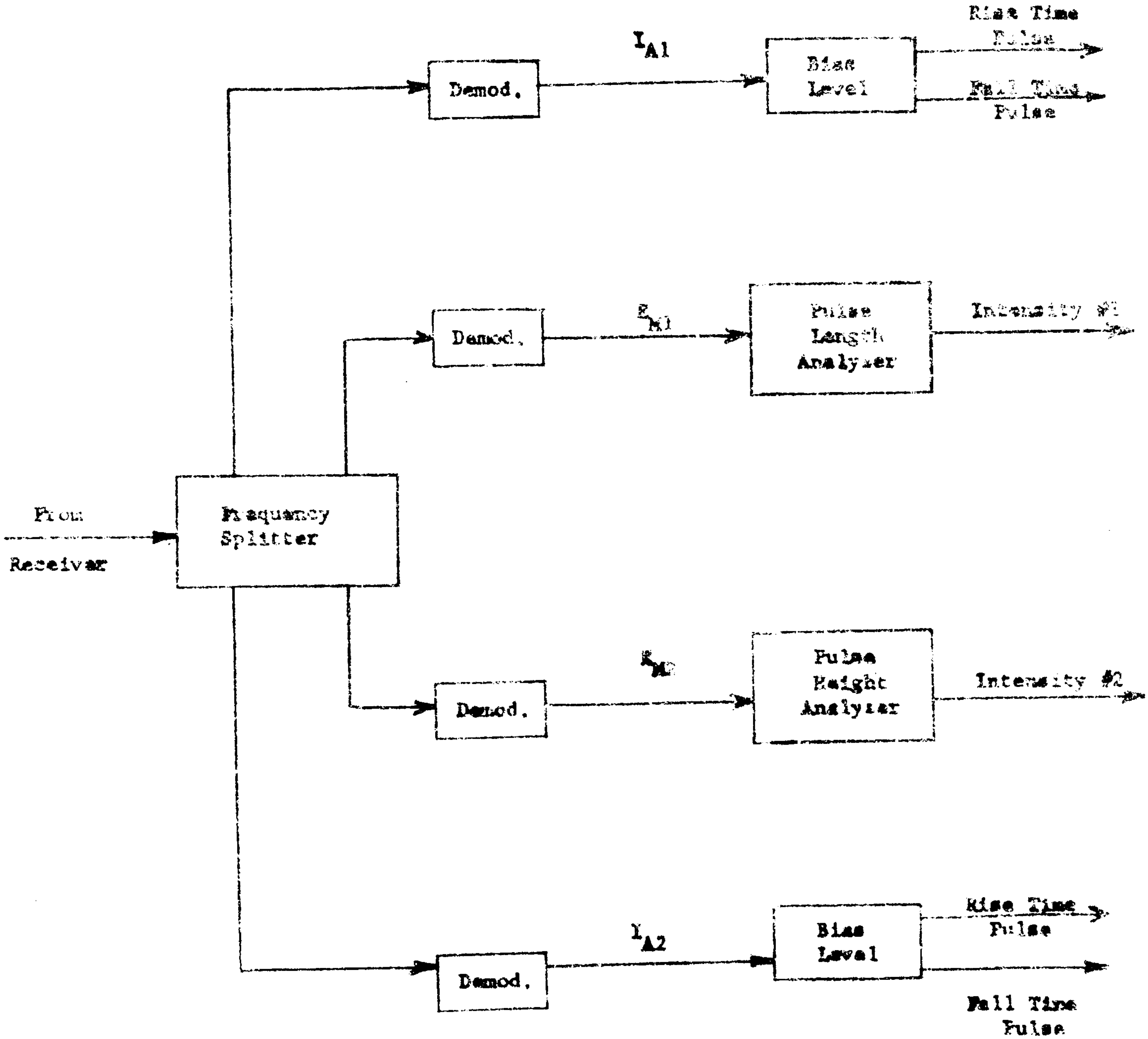


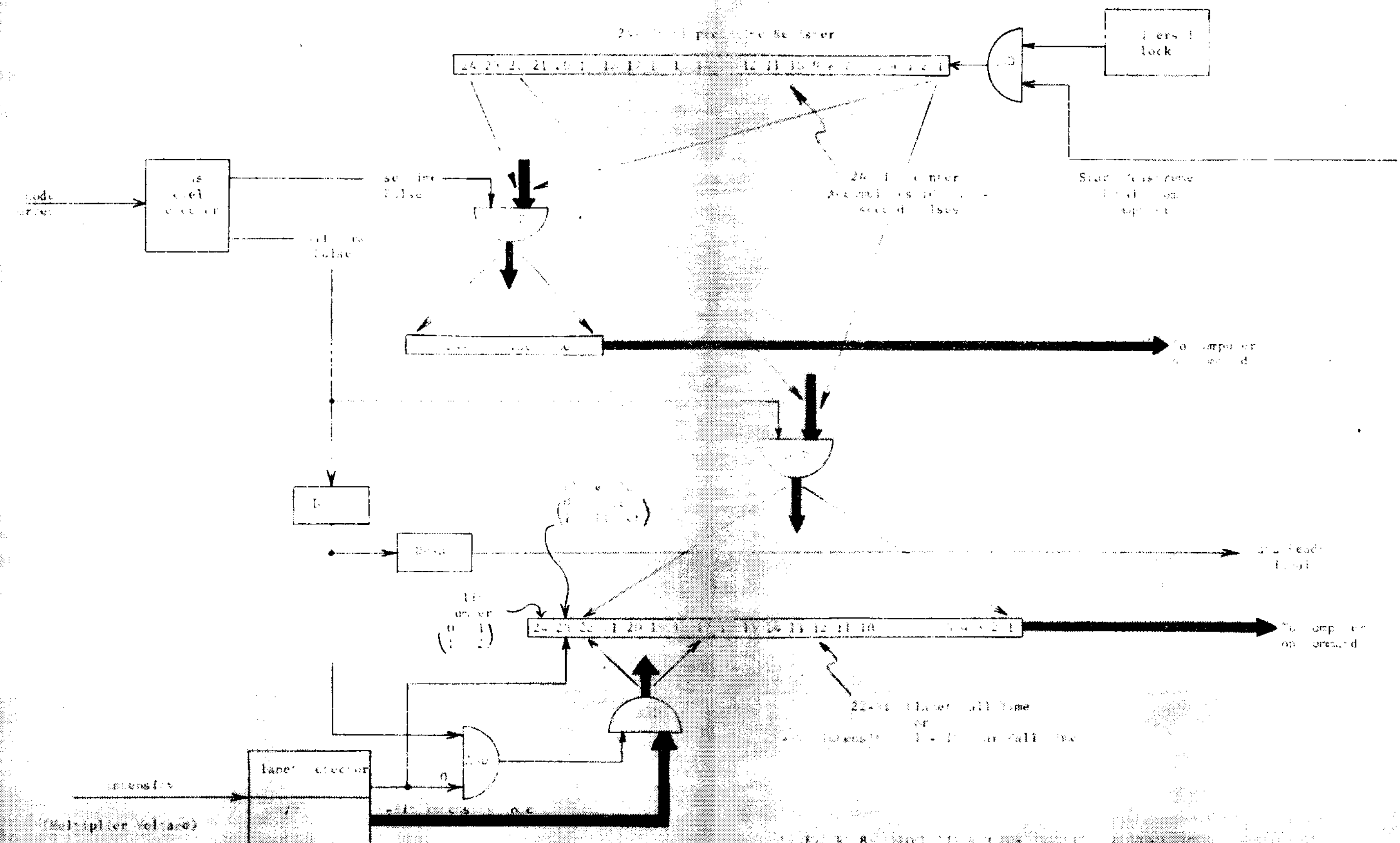
Figure 7: Schematic Representation of Vehicle Electronics prior to Data Formation Logic

Figure 8. Three registers, each 24 bits long, are shown. The first ("Elapsed Time Register") contains at any instant, the count (in 10 μsecond intervals) of the time from the start of the measurement sequence. This count is accumulated from 10 μsecond pulses generated by an external clock. The register will hold up to 168 seconds of time, well enough to encompass ten scan periods of ten seconds each, and will be able to resolve angles as small as one second of arc. (See Figure 3 and Section IIIB.)

When the anode current from the photomultiplier rises above a given bias level, a pulse is generated which gates the contents of the first register into the second ("Rise Time Register"). This latter then contains the time at which the anode current exceeds the bias.

The third register accumulates several quantities and its contents depend on the type of target detected. The reason for this is that planets are extended bodies, and in some cases the trailing edge rather than the leading edge of the planet will be measured. ("Trailing" and "leading" refer to the manner in which the slit approaches the planetary disk.) Since it is not known beforehand which is desirable, both the rise time (denoting the entrance of of the leading illuminated portion of the planet into the slit) and the fall time (denoting the exit from the slit of the trailing illuminated portion) need to be recorded.

The largest size of a planet, due to the slit configuration chosen, is 60° in diameter. Thus it is possible that one slit is



(Multiplier Voltage)

illuminated for 1/6 of a period or 1.667 seconds (ten second period) by a full disc planet. Using a 10 μsecond count resolution, such a dwell time would consume $1.667/10^{-5} = 166{,}700$ counts and could fill just over 1/2 of an 18-bit register.

For a planet, then, the second data word has its lowest 18 bits identical to the lowest 18 bits of the Elapsed Time Register at the anode current fall time.* Since intensity data is not needed for a planet, only two more bits are used: one denoting the slit number (0 means slit #1, 1 means slit #2) and one for a target tag (0 for stars, 1 for planets or any extended target).

The number of bits needed, therefore, is only 20 while Figure 8 shows a 24-bit word. This has been done merely to simplify the situation. The total number of bits produced is 24 + 20 = 44 which would fit in two words each 22 bits long. However, the computer will accept data equal to its word length, which we feel has a high probability of being in the 24-30-bit range. Furthermore, to retain the rise time in one unit, a 24-bit input is required; complicating the hardware by using words of different sizes seems unnecessary. For planets, then, the second word contains: a one-bit slit tag,

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* It is to be noted that these 18 bits are not used to count the dwell time; they merely reproduce the Elapsed Time Register at the fall time. Thus it is possible for this number actually to be less than the number represented by the lowest 18 bits of the Rise Time Register. Such an event would mean that the 19th bit of the Elapsed Time Register had changed between the rise and fall times. One is only concerned, therefore, in preventing this bit from changing more than once. This is ensured if $2^{18} - 1 >$ expected maximum number of counts. That is, the 18 bit counter can never overflow twice (regardless of where it begins the count) if the expected maximum number of counts is less than could be contained in such a register.

a one-bit target tag, and the 22-bit lower portion of the Elapsed Time Register at fall time.

So much for planets and other extended targets. Stars are much simpler in that, being almost point sources, they remain no longer than about 368 μseconds in the slit. To measure fall time, then, no more than six bits would be needed for counting. In order not to complicate the hardware, however, it is suggested that the 22-bit lower portion of the Elapsed Time Register be transferred to the second word upon receipt of the fall time pulse in the manner identical to that used for planets. In addition, after a short delay, bits 17-22 of this word are overwritten with the intensity code. The anode current rise time pulse, of course, transfers 24-bits between the Elapsed Time Register and the Rise Time Register also as is done for planets. For stars, then, the second word contains: a one-bit slit tag, a one-bit target tag, a six-bit intensity code, and a 16-bit fall time. Again the 16 bits are way in excess of what's needed, but compatibility with the planet detection procedure and uniformity of word length suggests these values.

In any event, shortly after fall time, the computer is informed that data is ready whereupon the two words are transferred either directly into the computer or into an intermediate buffer.

III. DATA PROCESSOR

A. Buffered I/O and Interrupt Features

Information will be entering and leaving a space computer in a variety of modes and rates. Furthermore, some of the data will be arriving at unpredictable times. To accomodate these requirements, two features of a space computer which are highly desirable are: (1) at least one buffered input/output channel, and (2) an interrupt capability.

The interrupt feature is, of course, almost a necessity when the computer is dealing with a wide range of problems each having a different priority level. For example, if the computer is currently engaged in transmitting scientific data to Earth when data suddenly arrives from a higher priority source, one would desire that the computer immediately devote its attention to this latter problem, but at the same time not destroy information being readied for transmission to Earth. This can be accomplished with "interrupt" in the following manner.

Upon receiving an interrupt signal, the computer automatically (i.e., by means of hardware) jumps to a pre-assigned location from which it extracts the next instruction. This instruction and the ensuing sequence of instructions performs the tasks of (a) storing any data which is pertinant to the original program and which might be destroyed in the present routine, (b) sensing which device caused the interrupt, (c) carrying out the necessary usage to remove the interrupt (this may merely be data input or may be serious enough scrap the present program for some "emergency" function), and finally (d) restoring the original program data and returning to it. In this manner, a number of functions can be monitored and updated "simultaneously".

The buffered input/output feature is most useful when blocks of information need to be transferred rather than one word at a time. Also, on input, data may arrive in a random fashion as it does from the scanning camera. Thus if two words arrive in close succession, the second one may be lost due to the computer being busy pre-processing the first. To avoid this, a buffer is added which retains information until the computer can accept it. In a sense, each input channel which contains a holding register is a buffer since the information is retained until the computer has available time to receive it. The word "buffer" is generally reserved for a multiple-word set of holding registers. This device can accept data from a certain sensor at an extremely high rate of speed (the "instructions" are all performed with hardware) and also operates independently of the computer.

A typical sequence might be as follows. While the computer is executing a given sequence, data arrives at the buffer in the form of single words, spaced in time. When the first word arrives, an interrupt is sent to the computer. Before the computer can exit from its sequence, however, several more data words may enter the buffer, being stored in it sequentially. The computer, when it enters the interrupt routine, empties the buffer of all its words and any that might enter even during this operation. Finally, the computer returns to its original sequence until the buffer, on receiving another word of data, interrupts again.

Because such a buffer stores incoming data sequentially, two index registers will probably have to be used. One will always contain the address of the next buffer location to be filled by incoming data. This is then stepped each time the data enters. The other index, or counter, contains the address of the next buffer location to be emptied by the computer, and this is also stepped each time a data word is transferred from the buffer to the computer. When the two indicies are equal, no data is in the buffer, while their difference denotes the number of words ready to enter the computer.

B. <u>Clocks and Time Keeping</u>

On board a space vehicle for any extended journey will probably be a highly accurate and stable oscillator which can be used to keep time. The output is in the form of a series of pulses which, on being added in a binary fashion to a digital counting register in its lowest bit, produces, in this counter the binary coded elapsed time. This in turn can be used to drive other devices such as an ordinary clock which reads in years, months, days, hours, and seconds. The counting register also can provide pulses at rates which are 1, 1/2, 1/4, 1/8, etc. of the original oscillator rate.

Let us say that time needs to be measured to an accuracy of one microsecond for a duration of ten years. The total number of counts in this interval is 3.15312×10^{14}. A binary register capable of holding this number must be at least 49 bits long. Such a register could actually hold a number as large as $2^{49} - 1$ or just under 5.63×10^{14}. With one microsecond resolution, it can keep time for almost 18 years.

More specifically for the scanning camera, as noted in Section II-B-3, registers are needed for the construction of the data words. Time is one of the measured quantities. Its accuracy is determined mainly by the measurement, since one does not want the clock to limit the navigational precision. The length of the measurement, that is the duration of the data gathering period, determines the size of the time number which will not be exceeded.

At the beginning of the measurement, the computer will read the main clock and also start an additional register counting ("Elapsed Time Register" of Figure 8). This latter counter then measures the elapsed time from measurement initiation. It is this time which is gated by the rise time pulse into a "Rise Time Register" prior to input to the computer or the buffer.

To determine the word length of the Rise Time and Elapsed Time Registers, let us assume that the camera will scan through a complete rotation N times and that the angular RMS error, σ, is given through the relation (1) of Section I. Since the ratio of the elapsed time

NT (T is the scan period) to the desired time resolution should be greater than the ratio of the total scan angle to the RMS angle error, and if we assume that one count is equivalent to the RMS angle error, the total number of counts required to measure the target transit time to the desired time resolution in a length of time NT is

$$\frac{2\pi N \times 2 \times 10^{5}}{\sigma} = 4\pi \times 10^{5} N T^{1/3} \left(\frac{D}{61}\right)^{2/3} \times 10^{-.133 m_p} \qquad (2)$$

where σ is in seconds of arc, D in centimeters, T in seconds, and m_p is the photographic magnitude of the target. We see that the total count depends on many design parameters since the angular resolution, σ, also depends on these. Thus the brighter targets (lower m_p) require a larger count since the angular measurement can be more accurate. Similarly for aperture size: increased D means more energy gathered and hence better target location.

If the counting register is n bits long, n must be such that

$$2^{n} - 1 \geq 8.14 \times 10^{4} N (T D^{2})^{1/3} \times 10^{-.133 m_p}. \qquad (3)$$

Using a 4 inch aperture (D= 10.17 cm.) and targets as bright as m_p = -1.5 magnitude, one can neglect the -1 on the left hand side of (3) with the result that minimum word length is given by

$$n > 19.19 + 1.11 \log T + 3.32 \log N. \qquad (4)$$

This relation is shown in Figure 9 for various scan periods and number of scans. One sees that not a great change takes place, but for the range of periods and scans chosen, the word length is between 19 and 25 bits for the transit time counter.

Viewed in another manner, one can consider the case where the word length in this counter contributes no greater error than a certain angular resolution. Table II shows such results for various scan numbers and angular errors. For example, collecting data for ten scans with a desired error below two seconds of arc requires that the word length be at least 23 bits long. This means that, while dimmer targets may cause a greater angular error and hence dominate the measurement, the brighter targets (those which contribute measurement errors below 2") will have their errors dominated by the finite word length of the counter.

In general, then, to be sure of the null effect of word length error and also to permit data collection over ten scans, the transit time counter should be 24 bits long. Furthermore, its lowest bit, in accordance with Figure 3, should not have a period longer than 10 μseconds.

C. Data Input and Pre-Processing Tasks

The camera data formed by the measurement electronics will probably not be in a form appropriate for use in the navigational equations. That is, the bit structure of a single word may contain values of measurements on several parameters (e. g., a 24-bit word could contain four values, each six bits long). Since different

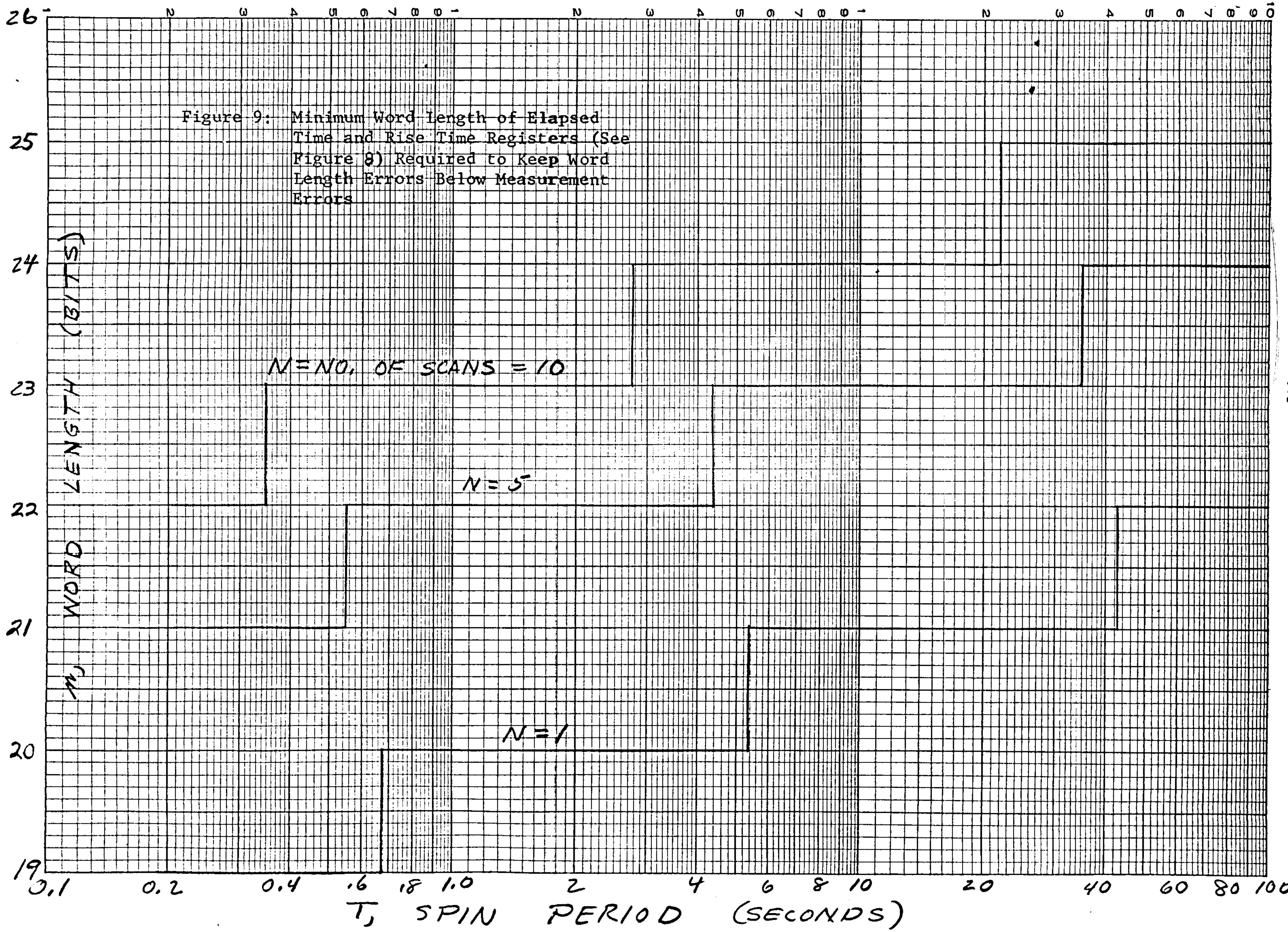


Figure 9: Minimum Word Length of Elapsed Time and Rise Time Registers (See Figure 8) Required to Keep Word Length Errors Below Measurement Errors

TABLE II: Minimum Word Lengths for Various Scan Numbers and Angular Errors, to Keep the Word Length Contribution Below the Measurement Error

Angular Error (sec)	Number of Scans			
	1	2	5	10
1	21	22	23	24
2	20	21	22	23
5	18	19	21	22
10	17	18	20	21

measurements are used in different portions of the data processing a certain amount of pre-processing must be accomplished to separate the data into their component parts.

1. Data Input

Entering the words into the computer is the first requirement. The consideration necessary here is: can the data be input and pre-processed at a sufficiently fast rate to prevent information loss? This rate is influenced by (a) the expected target rate, (b) the number of words that have to be input per target, and (c) the amount of pre-processing required. Actually, (a) has little effect on the computer since the target will remain in the camera slit for a comparatively long time. A ten second period and 23".1 slit width (effective), means that the photomultiplier illumination remains above 1/2 its peak value for

$$\frac{23.1}{277 \times 2 \times 10^{5}} \times T \times 10^{6} = 234.4 \mu sec.$$

This being a long time for ordinary computer speeds, the camera electronics, blur circle, and slit size will be the most critical determiners of target loss probabilities.

The number of data words constructed per target depends upon the basic word length of the computer itself and upon how much of the transit time word is contained in the camera electronics. This last requires some explanation. In Section IIIB we determined that

24 bits was a reasonable size for the transit time counter. Not all of this need be retained in the camera electronics, however. For example, if the 12 lowest order bits were contained here, and the computer notified each time this 12-bit counter overflowed, then the computer could count the overflows and essentially make up the other 12 bits of the full 24-bit counter. If the lowest order bit changes once every 10 μseconds, then the 12-bit counter will overflow every 0.41 seconds, an 18-bit counter every 2.62 seconds, and a 7-bit counter every 1.27 milliseconds.

Each time overflow occurs, however, the computer must be interrupted and must then update its part of the transit time counter. Also, when the data finally enters, the full 24-bit transit time will have to be assembled from its separate parts.

By putting some of the transit time counter bits in the computer, hardware is saved in the camera electronics section. But there is a resultant complication and added processing load on the computer. From the standpoint of reliability, there are many more operations involved in a split transit time counter thereby increasing the probability of a failure. Since the hardware saving is quite small, it is concluded that the full transit time word should be retained by the camera electronics.

From the numbers shown in Figure 8, then, we see that about 48 bits of data are generated for each target transit. According to the basic word length of the computer or input buffer, the number of data words are given by the following table. Because space

Word Length	Minimum # Data Words
48	1
24	2
18	3
12	4

computers will probably have word lengths smaller than 48 bits but not less than 18, the data will have to be accepted at the rate of 2 or 3 per target transit.

2. Pre-Processing

Let us assume for the following discussion that the computer has a 24-bit or greater word length, the first data word to enter is from the Rise Time Register, and the second consists of target tag, intensity, and fall time as shown in Figure 8. When data is ready to enter the computer from a certain slit, the sequence operating at that time is interrupted and another sequence, outlined in Figure 10, is executed. After accepting two words, it is determined whether a planet was definitely sighted (by means of the 23^{rd} bit in the second word). If it was, both the 24-bit first word (anode current rise time) and the 22-bit fall time will have to be retained separately until it is determined whether the leading or trailing planet edge is desired. This is not accomplished until the attitude can be found. Thus the rise time and 22-bit fall time are stored in a transit time list under the appropriate slit number. (The slit number occurs as the 24^{th} bit of the second word.)

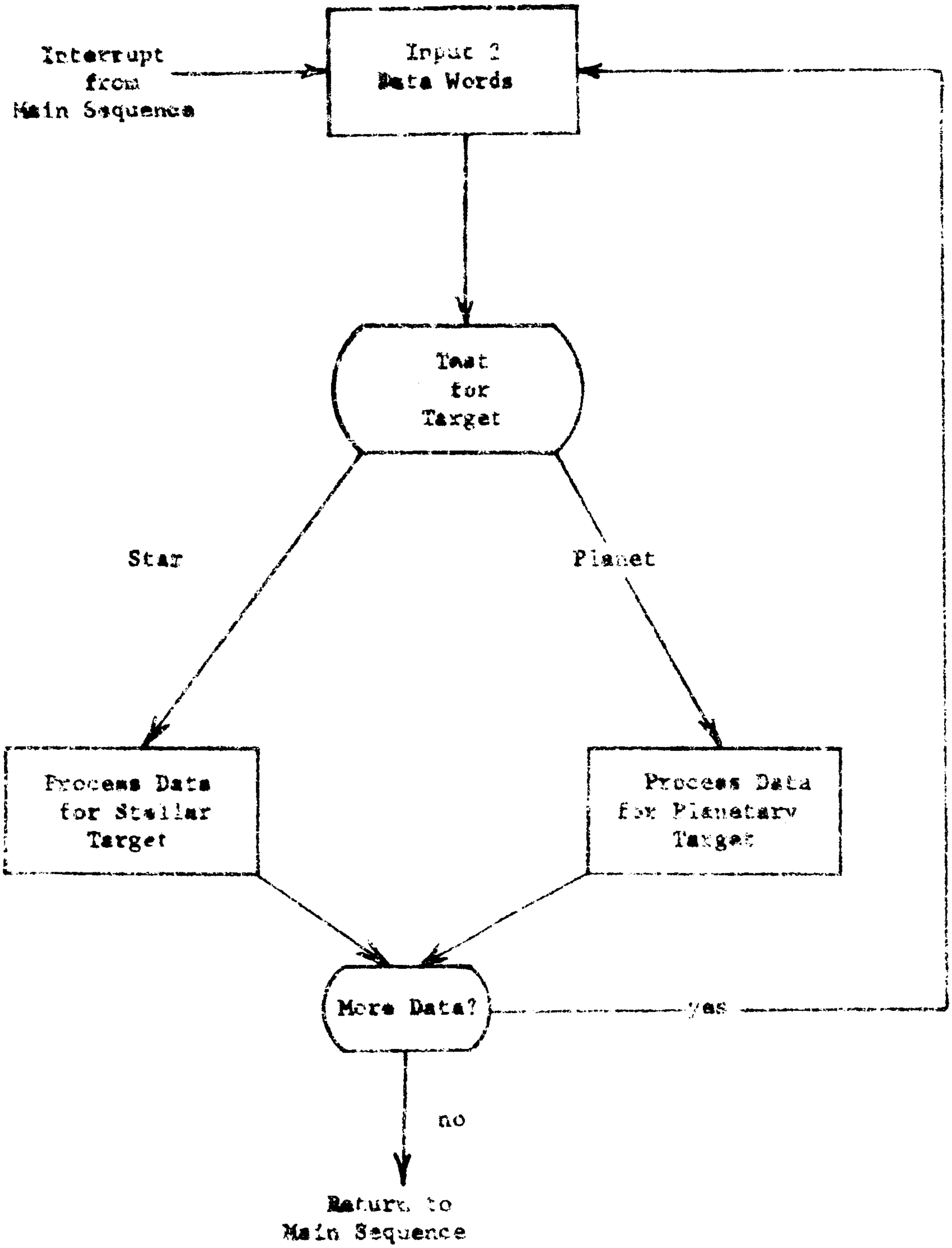
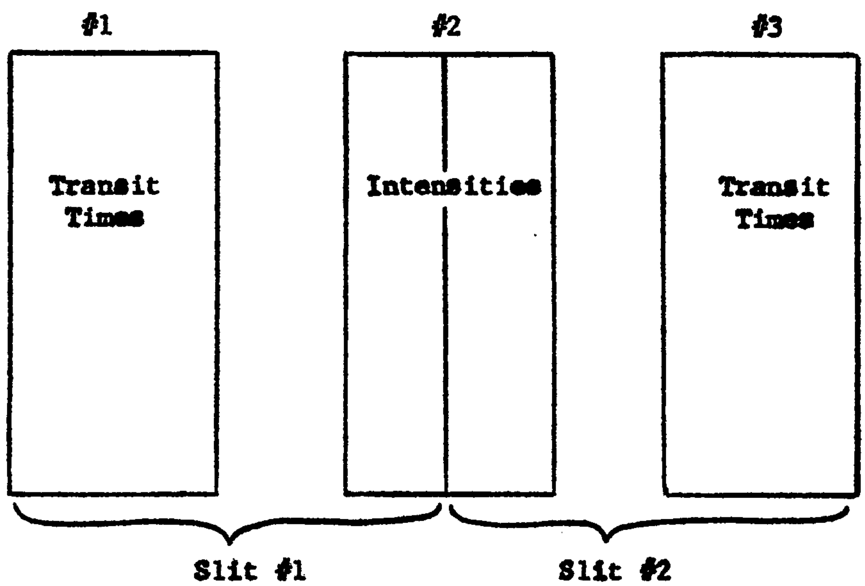


Figure 10: Flow Diagram for Data Input and Pre-Processing Interrupt Sequence

If the target appeared as a star, then the fall time is selected from the second word, divided by 2, and added to the first word. This then becomes the central transit time of the star and is stored under the appropriate slit. The intensity is then selected from the second word and also stored.

Assuming the computer has a word length of 24 bits or more, the transit time and magnitude data for stars are to be stored in their order of receipt in three lists. List #1 contains the 24-bit transit



times from slit #1; list #3 contains similar data from slit #2; list #2 contains the intensity data for both slits since each datum is only six bits along. The convention could be that slit #1 intensities always occur in the upper half of the word, slit #2 intensities in the lower half. Since data arrives and is stored consecutively, the third entry, for example, in list #1 corresponds to the upper half of the third entry in list #2 and so forth. Thus the location in either list #1 or list #3 automatically gives the location in list #2.

Even if the computer had a word length of 30 bits or more, it would probably not prove advantageous to store transit time and intensity data together since they would frequently have to be separated for the many tests and calculations performed during identification and the solution of the navigational equations.

It is suggested that a second set of lists be reserved for those targets definitely identified as planets (or at least extended bodies). Only two lists are involved here, one for each slit. The rise and fall times are stored for each slit consecutively. That is, the even locations, say, are occupied by rise times and the odd by fall times.

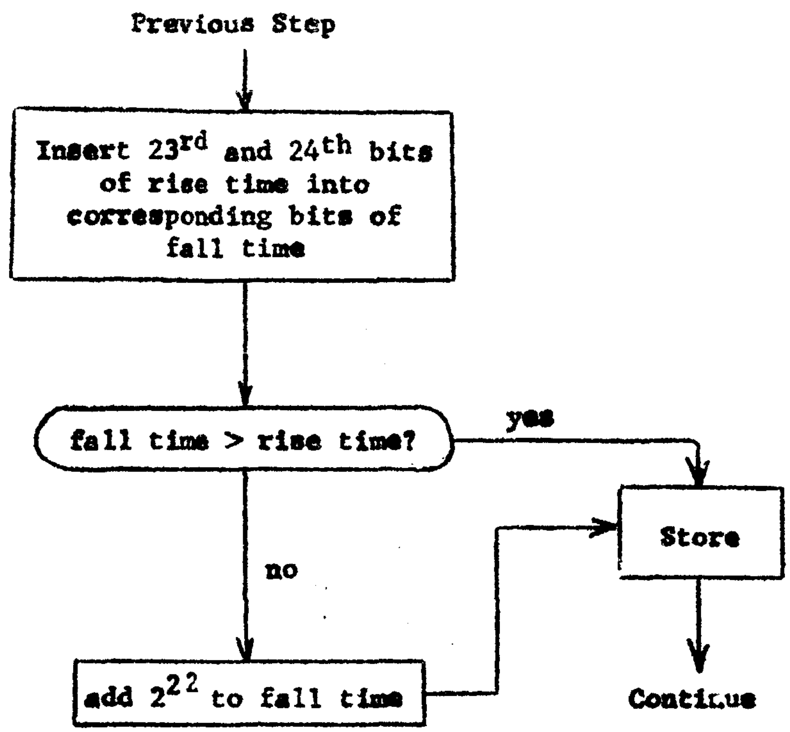
Slit #1

rise time	1
fall time	1
rise time	2
fall time	2

Slit #2

rise time	1
fall time	1
rise time	2
fall time	2

To construct a 24-bit fall time, the sequence in the sketch is followed. The leading two fall time bits are made identical to the corresponding rise time bits. The two numbers are then compared.



Since the fall time must exceed the rise time, and since the 22 bits of the Elapsed Time Register can have overflowed between these times only once, one bit is added in the 23^{rd} place if the fall time proves low. The results are then stored.

The program sketched here is treated in detail in TM-9552-8 which also includes estimates of the memory requirements and execution times.